DOCUMENT RESUME

ED 480 604 SO 035 338

AUTHOR	Judd, Michael; Lacasse, Jane; Smith, Monica; Reilly, Katie
TITLE	Invention at Play. Educators' Manual.
INSTITUTION	National Museum of American History, Washington, DC.
SPONS AGENCY	National Science Foundation, Arlington, VA.
PUB DATE	2002-00-00
NOTE	37p.; Developed by the Lemelson Center at the Smithsonian's National Museum of American History in partnership with the Science Museum of Minnesota. Support also provided by the Lemelson Foundation.
AVAILABLE FROM	Smithsonian National Museum of American History, 14th Street and Constitution Avenue, NW, Washington, DC 20560. Tel: 202-357-3306; Fax: 202-357-4945; Web site: http://americanhistory.si.edu/. For full text: http://www.inventionatplay.org/ iapeducatorsmanual.pdf.
PUB TYPE	Guides - Classroom - Teacher (052)
EDRS PRICE	EDRS Price MF01/PC02 Plus Postage.
DESCRIPTORS	*Creative Thinking; Elementary Education; Exhibits; *Inventions; *Play; *Science Education; *Social Studies; Student Educational Objectives; *Technological Literacy; United States History
IDENTIFIERS	*Inventors; *Smithsonian Institution

ABSTRACT

A Smithsonian exhibition was developed that looked at invention in an innovative way. It aimed to encourage visitors to make connections between their own lives and abilities and those of inventors. The role of play in the invention process was examined. Play is a universal and familiar activity and can help people find the link between their own experiences and those of the famed inventors in history books. This educators' manual is divided into the seven sections: (1) "Introduction Why Invention and Play?"; (2) "Exhibition Description"; (3) "Playful Inventors" (Borrow from Nature: Inventors: Alexander Graham Bell, Paul McCready, Activities; Keep Making It Better: Inventors: Newman Darby, Sally Fox, Activity; Find Opportunities in Obstacles: Inventors: Ann Moore, Krysta Morlan, Activity; Recognize the Unusual: Inventors: Stephanie Kwolek, Art Fry, Activity; Jump the Tracks: Inventors: James McLurkin, Chuck Hoberman, Activities; Many Heads Are Better Than One: Inventors: IDEO Company, Thomas Edison and Menlo Park, Activity); (4) "The Invention Playhouse"; (5) "Issues in Play Past, Present, and Future"; (6) "Invention and Play Quotations"; and (7) "Teacher Resources and References." (BT)

Reproductions supplied by EDRS are the best that can be made
from the original document.

ED 480 604

Educators' Manual

SO 035 338

Smithsonian
National Museum of American History

Lemelson Center for the Study of Invention and Innovation

BEST COPY AVAILABLE

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☑ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

Contents

1 Introduction—Why Invention and Play?

3 Exhibition Description

4 Playful Inventors

5 Borrow from Nature
Inventors: Alexander Graham Bell, Paul MacCready
Activities: Nature matching game, make a tube telephone

7 Keep Making It Better
Inventors: Newman Darby, Sally Fox
Activity: Clay boats

9 Find Opportunities in Obstacles
Inventors: Ann Moore, Krysta Morlan
Activity: Choosing a bike

11 Recognize the Unusual
Inventors: Stephanie Kwolek, Art Fry
Activity: Up close and personal with a polymer

13 Jump the Tracks
Inventors: James McLurkin, Chuck Hoberman
Activities: "De-engineering," mapping animal behavior

15 Many Heads Are Better than One
Inventors: IDEO company, Thomas Edison and Menlo Park
Activity: Make a lightbulb

18 The Invention Playhouse
Exploratory Play; Pretend Play; Social Play; Play with Patterns, Puzzles, and Problems

26 Issues in Play—Past, Present, and Future

27 Invention and Play Quotations

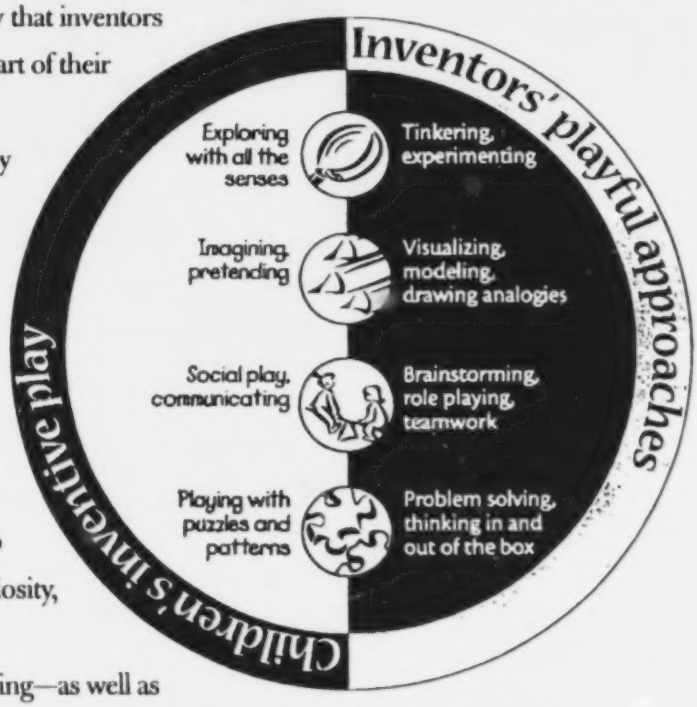
28 Teacher Resources and References
Standards, Bibliography, Websites, Videos

Why Invention and Play?

We faced two challenges in developing this exhibition. The first was to create an exhibition that looked at invention in an innovative way. The second was to create an exhibition that would encourage visitors to make connections between their own lives and abilities and those of inventors—to see that their inventive abilities may differ in degree but not in kind from the talents of people like Thomas Edison or Alexander Graham Bell. We decided to examine the role of play in the invention process. This approach was novel, rarely explored, and promised rich findings. In addition, play is a universal and very familiar activity, one that might help visitors find the link between their own experiences and those of the famed inventors in history books.

Play is a human activity with a long history. Evidence of human play has been found in archaeological sites around the world. Research in diverse fields of study, from history to anthropology to comparative psychology, indicates that there is a strong evolutionary link between play and development. This is true not only of humans but of all species whose members are born helpless and experience a relatively long period of development before reaching adulthood. It appears that animals that grow up slowly grow up playing, and that this activity is related to both physical and mental development and maturity. Play is engaged in for its own sake. It is open-ended and absorbing. Play is deeply satisfying, but not always "fun"; it can sometimes be arduous, frightening, and time-consuming. Yet it is something that all of us, especially children, engage in naturally, wholeheartedly, and as often as possible.

When asked what inspired them to become inventors, many adults tell stories about playing as children. Among inventors' most frequently cited childhood play experiences are: mechanical tinkering, fiddling with construction toys, reflecting in and about nature, and drawing or engaging in other forms of visual modeling. There is something about the fluid habits of mind fostered by play that inventors value and continue to use as part of their working lives. These playful approaches, used repeatedly by inventors and other creative adults, form an interesting parallel to the four kinds of play that child-development experts identify as more or less universal (see chart at right).


Inventors' playful approaches
Tinkering, experimenting
Visualizing, modeling, drawing analogies
Brainstorming, role playing, teamwork
Problem solving, thinking in and out of the box
Children's inventive play
Exploring with all the senses
Imagining, pretending
Social play, communicating
Playing with puzzles and patterns

Through play we develop certain "habits of mind"—curiosity, persistence, imagination, communication, problem solving—as well as skills in manipulating and understanding the properties of the material world. Our research has shown us that this array of abilities has been and continues to be an important part of the inventor's tool chest. The diaries and notebooks of 19th- and early-20th-century inventors and their colleagues and families provide historical evidence of the role of play in the invention process. Interviews and oral histories conducted with contemporary inventors add to the historical record of playful invention. We hope that this exhibition and manual will provide an array of activities, resources, and approaches that will underscore the role of play in the inventive spirit in all of us.

This exhibition brings a fresh perspective to the topic of invention, exploring the marked similarities between the ways children play and the creative processes used by innovators in science and technology. In 3,500–4,000 square feet of artifacts and interactive experiences, the exhibition provides visitors with opportunities to:

- Learn how play fosters creative talents among children as well as adults;
- Experience their own playful and inventive abilities; and
- Understand how children's play parallels processes used by inventors.

Invention at Play departs from the traditional representation of inventors as extraordinary geniuses who are not "like us" to celebrate the creative skills and processes that are familiar and accessible to all people. The exhibition was developed by the Lemelson Center at the Smithsonian's National Museum of American History in partnership with the Science Museum of Minnesota. The tour is managed by the Association of Science-Technology Centers. The exhibition has been made possible by the generous support of The Lemelson Foundation and the National Science Foundation. Artifacts are on loan from the National Museum of American History, inventors, and other organizations.

Invention at Play features three main areas:

- *Playful Inventors,* offering textual narratives, interactive devices, and artifacts that support explorations of the many ways inventors have used playful activities and skills in

their work. Five main inventors are featured, clustered with abbreviated stories about a wide variety of other innovators who have used similar creative techniques.

- *The Invention Playhouse,* where visitors of all ages can engage in four types of play that foster inventive thinking: exploration/tinkering, make believe/visual thinking, social play/collaboration, and puzzle play/problem solving.
- *Issues in Play—Past, Present, and Future:* What kinds of toys did inventors play with as children? Is the quality and quantity of children's play changing? How do new technologies affect children at play? This area, with its artifacts, video, and experimental playthings from the MIT Media Lab, encourages visitors to reflect on these and other questions concerning the history and future of play.

Playful Inventors

The exhibition displays colorful banners that provide clues to some playful approaches to invention, such as "Borrow from Nature" or "Recognize the Unusual." Under the banners are stories of a wide range of inventors, famous and little-known, whose creative habits of mind began in childhood play and resulted in a variety of useful contributions.

Borrow from Nature

GOAL: *To consider the possibilities of invention and play through the observation and exploration of nature.*

KEY CONCEPTS: Inventors often see connections that are not obvious to others. For example, a number of inventors have modeled innovative technologies on patterns in nature. Inventors also find areas in the natural world that serve as places for reflection and daydreaming. These habits of mind have their roots in the curiosity and fantasy play of children. Read the following stories of inventors whose explorations and imaginations have led them to "borrow from nature."

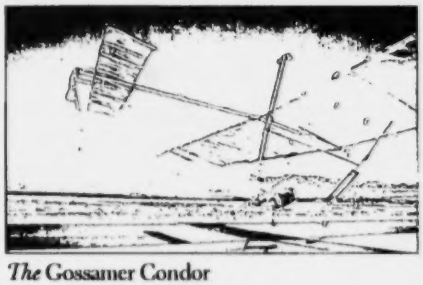
INVENTOR STORIES

Alexander Graham Bell, inventor of the telephone, found inspiration in the natural world in two ways. One was careful observation of how things work—the vibrations in the bones and membrane of the human ear, as well as the flight of birds and the properties of wind. The other source was his lifelong habit of reflection, often done out-of-doors. After studying how the human ear works during years as a teacher of the deaf, Bell came up with the initial concept for the telephone at his bluffside "dreaming place" near his parents' home in Canada. Then he spent months conducting experiments with his assistant, Thomas Watson, based on that idea. On March 10, 1876, Bell made the first successfully transmitted statement over the telephone: "Mr. Watson, come here, I want to see you." The Bell Telephone Company was formed the following year.

Bell working at his desk
Photo courtesy of Alexander Graham Bell National Historic Site of Canada

Bell's liquid (variable-resistance) telephone transmitter
Photo by Terry G. McCrea, courtesy of Smithsonian Institution

Paul MacCready conceived, designed, and built the *Gossamer Condor,* the first successful human-powered plane. MacCready went from building model airplanes as a child to earning a Ph.D. in aeronautics from the California Institute of Technology in 1952. Inspired by his theoretical knowledge of the soaring patterns of birds, his *Gossamer Condor* made history in 1977 by completing the one-mile-long, figure-eight route required to win the Kremer Prize of approximately $95,000 for the first flight of a human-powered airplane. MacCready used balsa wood, cardboard, Mylar plastic, and piano wire to construct this plane, which has a 96-foot wingspan but weighs only 70 pounds. The *Gossamer Condor* has earned a place of honor near the Wright brothers' plane in the Smithsonian's National Air and Space Museum.



The Gossamer Condor
Photo courtesy of Paul MacCready

CLASSROOM ACTIVITIES

Nature Matching Game

Display pictures of the following burrs, gourds, leaves, thorny plants, spruce trees, Venus flytraps, tomato worms, milkweeds, silkworms, and thunderstorms. Also ask students to collect and bring in samples from nature. Next, provide the following list to the students and have them try to match from the list human inventions inspired by the pictures and samples.

Zipper	Velcro
Shoes	Baby rattle
Paper money	Tent
Toothbrush	Barbed wire
Syrup	Chewing gum
Flyswatter	Bear trap
Vacuum-cleaner hose	Flexible pressurized suit
Powder puff	Parachute
Flashlight	Sound and light show

Ask students to find other things in nature and match them with human inventions.

Make a Tube Telephone

This activity will help the students understand what Alexander Graham Bell was thinking about when he began his experiment to enable people to communicate with each other from a distance. Contributing to Bell's design for the telephone was his understanding of the principles of sound and the way sound travels through space. His experience as an educator of the deaf had given him an appreciation of the way the human ear works and the way that sound is transmitted and interpreted. In this exercise students can observe some of the challenges of transmitting sound over distances. This activity can be done in the classroom or outside . Have the children experiment with different lengths of hose and graph the success they have in communicating with each other as they establish more distance from one another.

Materials needed:

- old garden hose
- pairs of plastic funnels
- penknife

Directions:

Cut up old garden hose in pieces as long or short as you want them to be. Push a funnel into each end (after cutting off the metal couplings from the ends of the hose). The tube telephone can have many twists and turns. Talk to a friend by speaking into the funnel at your end and listen to your friend by holding the funnel to your ear. Change the distance between the telephones and see if the distance affects sound and clarity. What happens when the "line" goes limp? Does that affect sound? What happens when you stretch the "line" around a corner?

IN THE EXHIBITION

Encourage students to look at the photomural of the "dreaming place" where Bell came up with his idea for the telephone. Do the students have a "dreaming place"? If so, where is it and what do they dream about there? Have them try Bell's phonautograph. Investigate the "Borrow from Nature" mural. Which inventors do they think were inspired by nature?

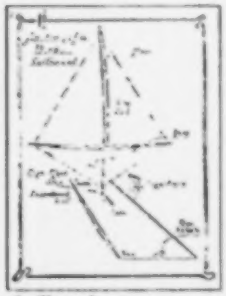
Keep Making It Better

GOAL: *To explore the playful processes of invention through experimentation and tinkering.*

KEY CONCEPTS: Inventors, like children at play, are persistent, curious people. They keep trying, sometimes over a period of years, to improve their inventions. Often they have to overcome numerous obstacles to perfect their work.

INVENTOR STORIES

Newman Darby, inventor of the sailboard and of improvements to catamarans and kayaks, traces his lifelong avocation to a childhood determination to build a boat that would carry him to an island where he hoped to find Native American arrowheads. Though his first design, at the age of twelve, failed, he continued experimenting. Two years later he constructed his first working boat. Darby's sense of adventure carried into adulthood when he designed a variety of watercraft, including the first sailboard in 1964. Darby exemplifies the virtue of persistence and repeated experimentation, as proven by the fact that, forty years later, he continues to make his sailboard better and to design new kinds of watercraft.



Sailboard
Illustration by Newman Darby

Sally Fox's personal interests in spinning and weaving, combined with her dedication to preserving the environment, led to the development of Fox Fibre, the first commercially spinnable naturally colored cotton. Fox produced it by continually crossbreeding colored cotton plants in search of fibers long enough for use in larger, commercial spinners. "When I started my work ... I hadn't read all the plant books saying you couldn't raise spinnable, naturally colored cottons. So I was blessed with ignorance, and thus went on." One of the environmental advantages of this naturally colored cotton is that it eliminates the need for potentially poisonous chemical color dyes. And a surprise bonus is that the brown cotton is naturally flame-resistant—perfect for use in children's sleepwear! Fox's cotton-breeding experiments have grown into a prizewinning, forty-acre enterprise, Natural Cotton Colours, Inc.

Darby on the first sailboard, 1964
Photo courtesy of Newman Darby

CLASSROOM ACTIVITY

Clay Boats

While doing this activity, ask the students to think about Newman Darby's quest to reach his island. Through trial and error, they will be reproducing many of the same processes that he went through to build and perfect his sailboards and boats.

This activity can be done using buckets and bowls in the classroom, but is more fun done outdoors in a small stream. It explores the properties of buoyancy and hydrodynamics in boatbuilding and encourages students to experiment with different sizes, shapes, and compositions of materials before selecting their best design.

Materials needed:

- clay
- paper clips
- small weights
- containers of water or a small plastic pool set up outside and filled with water

Directions:

Students will experiment to discover how an object that might ordinarily sink in water—such as a lump of clay—can be made to float. Through the shaping of the clay in various ways, children will find that some designs float better than others. They can then load their boats with common classroom objects or small uniform weights to find out how much "cargo" the boats can carry and which designs support the most weight. This activity can be extended by experiments with plastic cups, aluminum foil, and other materials to test ideas about buoyancy. All observations should be recorded with the use of graphs.

IN THE EXHIBITION

Encourage students to try the sailboard simulator. Windsurfing is a very popular sport. A device similar to this is used in resorts for the purpose of training beginners to windsurf. Ask your students to compare Newman Darby's first sailboard to today's version. How are they the same? What modifications have been made to the original design? Try out the universal joint and see how it works.

Find Opportunities in Obstacles

GOAL: *To help students understand that inventors are experts at problem solving and overcoming obstacles. A need is often the spark that drives the invention process.*

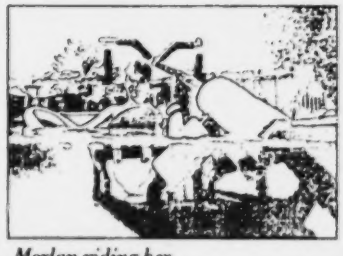
KEY CONCEPTS: Frequently inventors develop ideas because of a specific need. For example, growing up with cerebral palsy led Krysta Morlan to invent the Cast Cooler and a Waterbike to help her solve some health-related problems. And Ann Moore invented the Snugli when she had her first baby and wanted to find a better way to carry her child around.

INVENTOR STORIES

Ann Moore, a Peace Corps nurse serving in Togo, West Africa, admired the way African mothers carry babies in fabric slings tied to their backs while working. This experience was the first step in a journey that led her to invent the original soft baby carrier—the Snugli—as well as other specialized carrying cases. When she had her first child she tried tying the baby to her back in the African way, but found that the baby kept slipping. Moore and her mother, Lucy Ackerman, designed a simple backpack, which she was able to use while riding her bike, running errands, and cooking. Friends and neighbors saw the baby carrier and wanted one. In a very short time Moore and her family could not keep up with the demand for this popular product. They formed a company to produce the carriers, then later sold the rights to the Snugli to a manufacturer. Ann and her husband continued to develop improved baby carriers, later producing the Weego, a modernized version of the 1960s Snugli. More recently, Moore has been inventing carrying cases for medical and high-tech instruments.

Moore carrying a baby in a Weego
Photo courtesy of Ann Moore, Weego

While a high school freshman, **Krysta Morlan** faced the prospect of having both her legs in full casts for the entire school year due to surgery for diplegic cerebral palsy. In the heat of summer, Morlan quickly found that a cast irritates the skin, making it sweaty, itchy, and, worst of all, unreachable. She discovered that ventilating the area covered by the cast would solve the problem. She ran a narrow, flexible plastic tube between the underside of the cast and her skin and then attached the tube to a small, light air pump powered by a nine-volt battery. The pump drew in air and channeled it through the tube to the surface of the skin. She then solved a final problem by anchoring the device to the cast with Velcro, so it would lie flat and nearly unnoticeable. The Cast Cooler worked perfectly. Morlan's invention earned her the first national Lemelson-MIT High School Apprenticeship award in 1999. Working with "invention mentor" Colin Twitchell, director of the Lemelson Assistive Technology Development Center at Hampshire College, Morlan's inventive mind and eagerness to help others have resulted in the working prototype of a Waterbike. It can be used for physical therapy, which Morlan originally intended, or just for fun.

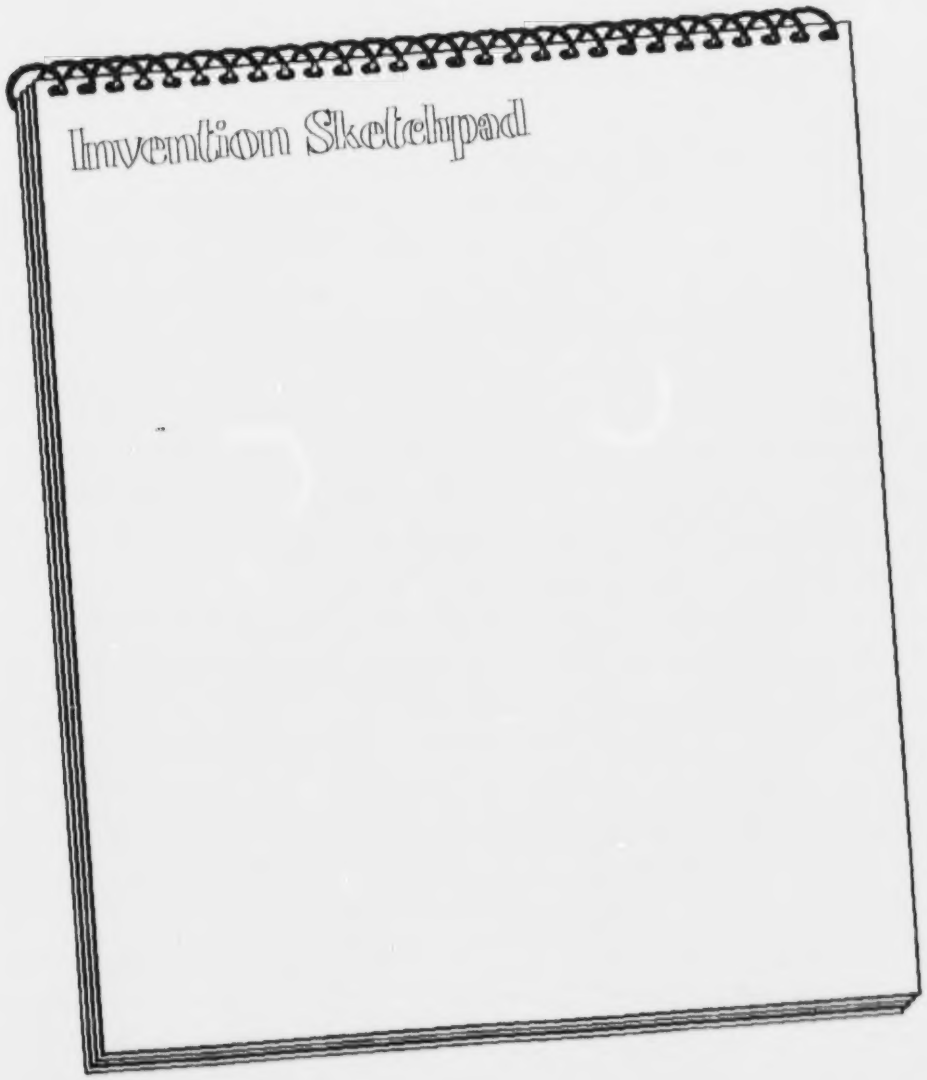


Morlan riding her Waterbike
Photo by Dan Auber, courtesy of Kathy Morlan

CLASSROOM ACTIVITY

Choosing a Bike

Begin by having the students imagine they are preparing to select and purchase a bicycle. Measuring the choices available through application of criteria is the best way of choosing. Criteria for selection might include items such as cost, durability, comfort, appearance, speed, and braking power. They might also include the specific needs of an individual rider. Sometimes such needs can be met only by designing a machine that meets the rider's requirements. Have the students discuss what criteria might be important in selecting a bicycle for special needs or for different terrains. Ask them to draw their conception of what such a bicycle might look like and to label the parts of their design that are there to solve certain specific problems.



Recognize the Unusual

GOAL: *To focus on the importance of persistence in seeking solutions and the ability to recognize the unusual and see its possibilities when inventing.*

KEY CONCEPTS: Inventors are always looking for different ways of doing things. Stephanie Kwolek's ability to recognize possibilities where others did not is a quality she shares with many inventors. This ability to see non-obvious connections and relationships often leads inventors to the key insight that is the basis for their invention. Sometimes it seems as if the inventor had a flash of inspiration or a "Eureka!" moment. But often these instances are the consequences of a lifetime habit, begun in childhood, of curiosity, exploration, and refusal to give up when faced with failure.

INVENTOR STORIES

As a child, **Stephanie Kwolek** dreamt of being a fashion designer but also enjoyed spending countless hours exploring nature with her father. Excelling in science and math classes, Kwolek decided she wanted to become a doctor. But she didn't have enough money to go to medical school, so she went to work as a chemist at DuPont's Textile Lab, where she learned how to make long molecules, called polymers, into fibers. Kwolek was challenged to search for high-performance fibers that were lightweight yet strong and wouldn't melt at high temperatures. One day in 1965, Kwolek dissolved a very stiff chain polymer in a liquid and found that something peculiar had happened to it. She reported that the resulting solution had become cloudy and like water. This substance was unlike anything she had previously observed in the laboratory. She was convinced that this polymer solution could be spun into usable, lightweight fibers and, with difficulty, she persuaded her colleagues to spin the solution. The resulting new fibers were surprisingly strong and stiff, exceeding everyone's expectations. Kwolek's discovery of "liquid crystalline solutions of extended chain aromatic polyamides" was the basis for what later became Kevlar. Her discovery was, she says, "a case of serendipity, combined with knowledge, experience, and perseverance."

Art Fry was a tinkerer and a new-products developer at 3M. His earliest engineering efforts were devoted to creating custom-designed toboggans from scrap lumber. In 1974, Fry became frustrated while singing in his church choir because the paper bookmarks that he used to mark the songs in his hymnal would slip out of sight or onto the floor. A few years earlier, 3M chemist Spence Silver had developed a weak, low-tack adhesive that no one knew how to use. Remembering this "unsuccessful" glue, Fry thought maybe it could be adapted to make a reusable bookmark. He made some samples for coworkers, who immediately found lots of uses for them. "I came to the very exciting and satisfying realization that those little, self-attaching notes were a very useful product." It took Art Fry and the 3M team several years to perfect the specifications and to design machines to manufacture the product, but in 1980 Post-it Notes were introduced nationwide.

CLASSROOM ACTIVITY

Up Close and Personal with a Polymer

This activity will give the students an opportunity to develop observation skills and practice in recording and comparing information. Recognizing the "normal" is a prerequisite for developing a sense of the unusual. An interesting exercise for the development of these necessary skills is observing and documenting the properties of polymers (large molecules made of identical parts linked together). These substances have unique properties that are fun to observe and test. Polymers have changed people's lives in the last hundred years. Today most households contain numerous items made from plastics or other synthetic materials. These materials have unusual qualities, such as superior strength, durability, and elasticity, yet they are remarkably easy to make. Students can easily make nylon or other non-harmful polymers in a laboratory setting. An excellent introduction is the "Outrageous Ooze" kit from the Wild Goose Company, which even contains edible polymers.

Materials needed:

- samples of synthetic polymers (bubble wrap, packing "peanuts," plastic wrap, plastic food-storage bags, trash bags, soda bottles, old serving containers, Styrofoam cups, plastic utensils, transparent tape, balloons, shower-curtain pieces, vinyl, toothbrush, plastic toys)
- dish or glass
- water
- magnet
- lab book

Directions:

Choose one to three samples of synthetic polymers. Record the name and draw a picture of each one. Examine and describe each sample in detail and record your observations. Be sure to consider these characteristics: size, shape, weight, color(s) and decoration, smell, flexibility, tears or breaks easily, waterproof, attracted to magnet, handmade/machine-made, molded in one piece/in several pieces, recyclable, used/new, floats/sinks, function. Then answer the following questions:

- What material(s) could be used instead of plastic to make this object? Should other material(s) be substituted?
- Is the object environmentally "friendly" and can the plastic be recycled?
- How would the object be physically different if it were made of these other materials?
- How would the function of the object be changed if it were made of a different material?
- Is plastic a good material for this object? Does making the object out of plastic improve or hinder the function of the object?
- Does the value of the object change when it is made of plastic?
- What can you conclude about the use of plastic for this object?

IN THE EXHIBITION

Encourage students to examine the island created entirely out of Kevlar products. It includes touchable objects with tags that encourage visitors to find out how Kevlar improves these products. Also in this area is a testing station where students can compare the weights of a Kevlar rope and a standard steel cable and of two bullet-resistant vests, one made of Kevlar, and the other an old-fashioned "flak jacket." Can you see the indentation of the bullet in the Kevlar bullet-resistant vest? Nearby, flip panels tell the stories of other inventors who have recognized and capitalized on the unusual properties of things.

Kwolek holding a Kevlar thread
Photo by Michael Branscom, courtesy of Lemelson-MIT Program

Jump the Tracks

GOAL: *To help children discover how inventors "jump the tracks" or "think outside the box" by breaking patterns and finding new connections.*

KEY CONCEPTS: Some of the creativity of childhood comes from the fact that children are only beginning to learn the accepted patterns and categories of thinking—the rules for the way things go together that adults take for granted. Because they don't know the rules, children, like many inventors, make interesting connections and leaps between different categories of knowledge, what we call "jumping the tracks," to find solutions to problems. Inventors are good at applying data from one field or discipline to another. They often see connections in unrelated fields that are not apparent to others. Inventors, and children, are often multidisciplinary thinkers. Creative thinkers in many fields seem to have a facility for breaking out of generally accepted categories to create new patterns or combinations.

INVENTOR STORIES

McLurkin holding one of his robotic ants
Photo by Donna Coveney, courtesy of MIT News Office

James McLurkin is a young engineer who applies biological principles to innovation in robotic technology. He studied and observed the behavior of real ants as he designed his microrobots. He believes that "mechanical things are easy to start with because they're in your world, they're physical, you can measure them, take them apart, and see how they work by looking at them." He calls his microrobots "ants" because they work together as the insects do. McLurkin has programmed the "ants"—which he builds with the help of friends—to respond to their environment; the microrobots can hunt for food, pass messages to one another, and even play tag. These "ants" have the potential for performing simple household jobs and assisting with some medical procedures. James McLurkin dreams of teams of microrobots cleaning up a dump, with some robots gathering metal and others gathering plastic and so on. These days he is designing small hopping robots that could be used on Mars. He [illegible]ys interested in learning more about elements from the natural world that can be applied to robotics.

Chuck Hoberman started out wanting to be an artist. He next studied engineering. He now calls himself a "folder" because he invents objects that seem to unfold and fold themselves. Besides the Hoberman Sphere, Hoberman has invented a flying disk, a collapsible tent made of only one piece of plastic, and a briefcase that folds down to the size of a purse. For Chuck Hoberman, invention is part imagination and creative spark, and part hard work and perseverance. These days Hoberman is dreaming of building a stadium or amphitheater roof that closes and opens as his Sphere closes and opens. He has said, "If it's the structures that get famous, and I get a little famous too, then that's okay. But the first thing I'm thinking of is how to make the dream happen."

Hoberman demonstrates his invention to a group of schoolchildren
Photo by Eric Long, courtesy of Smithsonian Institution

CLASSROOM ACTIVITIES

"De-engineering"

One of James McLurkin's favorite activities as a child was "de-engineering." Even today he collects parts, gears and motors that help him in prototyping his robots. By taking apart toys, appliances, and other mechanical products, children learn how they work. Today's youngsters often have no idea how simple machines, or the technologies behind the inventions they use, operate. By engaging in de-engineering activities, they can often bridge this gap. This activity will help students better understand how things work when they are given an opportunity to take things apart.

Materials needed:

- safety goggles
- screwdrivers (both regular and Phillips),
- pliers
- broken equipment--radios, irons, clocks, etc. (note: please remove the plugs before giving the appliances to students)
- journals

Directions:

Working with a partner and wearing safety goggles, students should carefully take the piece of equipment apart, recording interesting facts in their journals. Students can also identify the parts they find and describe the function of each. A summary of how the equipment works can be written, giving what the students found as they "de-engineered" their piece.

McLurkin's ant drawings in his notebook: "The ants are coming."
Notebook page courtesy of James McLurkin

Mapping Animal Behavior

James McLurkin takes what he learns from entomology (the study of insects) and applies it to small robots. By studying ant colonies and beehives, robotic engineers are able to analyze tasks for robots and predict how they will respond. The ability to observe accurately and record one's observations is therefore an important skill for inventors. The knowledge gained in this systematic observation can then be used in a variety of ways. In this activity students will be observing ant behavior. The project will help students become more observant and also give them practice in recording their observations.

Bring an ant farm into the classroom and have the students record their observations. Some naturalist centers and museums have live bee colonies and ant farms as part of their exhibits. The Natural History Museum in London even has an electronic version. Ant farms are great fun and basic kits are available from supply companies like Berkshire Biological Company. Usborne Young Naturalist Guides are also very helpful, and there are even chat lines on the web for enthusiasts who are keeping ant farms.

Have students answer the following questions and record their answers in a naturalist's journal.

- Ants tend to specialize in their functions. Can you recognize which ants do which jobs in the colony? Do they look different from each other? How?
- Make a list of the tasks you see the ants doing.
- What kinds of objects do you see them carrying?
- When two ants meet, what happens?
- Do several ants cooperate in doing certain tasks? What kinds of tasks?
- What are the functions of the queen ant?
- How do ants communicate?

IN THE EXHIBITION

Encourage students to view the video that compares McLurkin's microrobots to real ants. Read about McLurkin's childhood and his inventive career so far. What kinds of interests led him to explore microrobots? What parallels do you see between his microrobots and insect life?

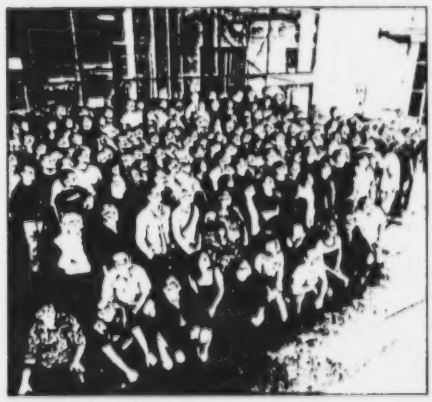
Many Heads Are Better than One

GOAL: *To understand that teamwork and collaboration are important aspects of the invention process.*

KEY CONCEPTS: A common stereotype is that of the lone inventor. Although inventors often come up with unique ideas on their own, many of them work with other people. While inventions are being developed, inventors frequently discuss and test them with family, friends, or colleagues. Inventors today typically work in teams in laboratories or corporations. IDEO is an innovative product design company known for its playful corporate culture that exemplifies the value of collaboration and teamwork. Its team approach has historic roots in the "invention factory" that was actually one of Thomas Edison's most important innovations.

INVENTOR STORIES

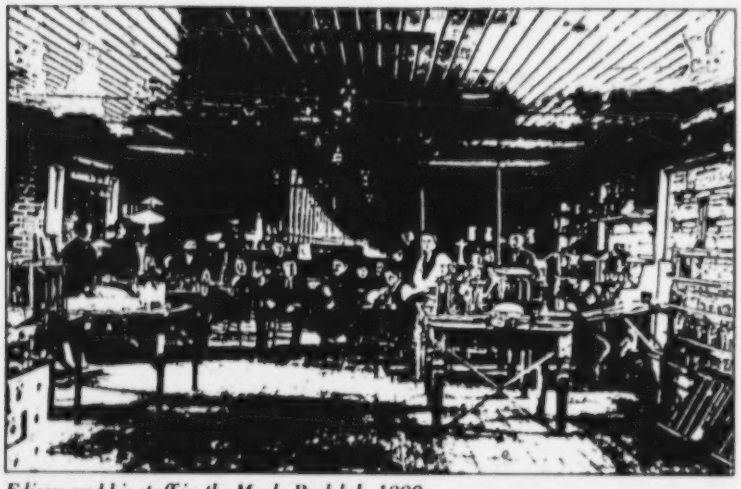
At **IDEO,** experts from a variety of fields come together to create products, services, and environments for their clients. IDEO's multidisciplinary teams include specialists in areas such as human factors, cognitive psychology, business strategy, industrial and graphic design, architecture, mechanical and electrical engineering, software, and manufacturing. For any project they work on, IDEO teams use a five-step process: understand the problem, observe, visualize, evaluate and refine, and implement. IDEO's strength lies in this team approach, where members share and improve ideas, build on each other's skills, and work together to solve problems. They also play around a lot. As IDEO founder David Kelley says, "Fresh ideas come faster in a fun place." Well-known products designed by IDEO include the first Apple computer mouse, the Palm V, and the Neat Squeeze toothpaste tube. IDEO is one of the many innovative companies that have



IDEO's Palo Alto office
Photo courtesy of IDEO

historical roots in the famous research-and-development lab created by **Thomas Edison** in Menlo Park, New Jersey, in 1876. The Menlo Park "invention factory" built on the 19th-century craft-shop model of invention and pointed toward the corporate R&D labs to come. Edison's strategy was to expand his own talent and capabilities by working with a team of scientists, machinists, carpenters, glassworkers, and other specialists. He boasted, "[My lab will produce] a minor invention every ten days and a big thing every six months or so." Edison came up with ideas, making notes and drawing sketches in lab notebooks, and worked with his staff to turn them into practical devices. They conducted experiments and solved problems, and Edison was open to suggestions and ideas about new experiments and inventions. Edison's enthusiasm, energy, and strong work ethic were infectious. The staff worked sixty to eighty hours a week, often through the night, especially when a project was on

the verge of success. But it wasn't all work and no play. For relaxation, Edison occasionally played an organ located against the back wall of the lab, and there were rowdy sing-alongs as well as storytelling and practical jokes and pranks. Edison also sometimes used the lab's experimental electric train to transport the staff to a local fishing hole. Within six years of the lab's founding, Edison, the "Wizard of Menlo Park," earned more than 400 patents for a steady stream of inventions. They include the phonograph, a carbon telephone transmitter (the microphone in the telephone mouthpiece), the first practical incandescent lightbulb, and the electrical generating and transmitting system to make the lightbulb commercially feasible and successful. And by 1931, when Edison died at the age of eighty-four, he had 1,093 patents—more than any other inventor in U.S. history.



Edison and his staff in the Menlo Park lab, 1880
Photo courtesy of Smithsonian Institution

CLASSROOM ACTIVITIES

Make a Lightbulb

Edison and his team accepted the challenge of producing a practical working lightbulb. They tried hundreds of filaments before they found one that would work. They tested everything from cardboard and palm leaves to bamboo and hemp. This activity works best when it is done with groups of students, with one designated as a timekeeper. Participants will want to compare their results. The first few tries will last only a couple of seconds, but with practice, students will be able to keep their bulb lit for up to forty seconds. This activity is designed to demonstrate 1) the processes involved in inventing as a group and 2) the difficulties the Edison team encountered in developing a workable lightbulb.

Important Safety Hints: This experiment should be done with adult supervision. Have children wear safety glasses and gloves while doing the experiment. They should handle the filaments carefully when they burn out, as they will be hot. The supervising adult should caution children never to play with wall sockets or household electric current.

Materials needed:

- small jar
- cork stopper for a lid
- three feet of shielded copper wire
- one six-volt battery (not a car battery!)
- thin iron wire (the best source for this is unraveled picture-hanging wire)
- small notebook to record what worked and what didn't

Directions:

- First cut the copper wire into two lengths about eighteen inches long. Cut off an inch of the plastic coating at each end of the strands.
- With a nail, drill two holes into the cork. Push the wire through the holes so that about two inches of the wire will be seen in the jar.
- Make a hook at the end of the copper wires so that you can twist small strands of iron wire around them to make a filament.
- Twist several strands of iron wire together and stretch them across the gap between the two copper hooks to form the filament.
- Put cork stopper with filament inside the jar.
- Carefully hook up both copper wire ends to the battery and watch your lightbulb light up!
- Keep a record of how long your filament lasts.

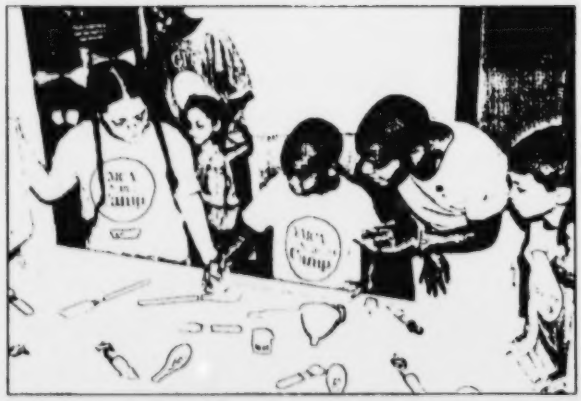
CAUTION: FILAMENT WILL BE HOT.
DO NOT TOUCH IT!

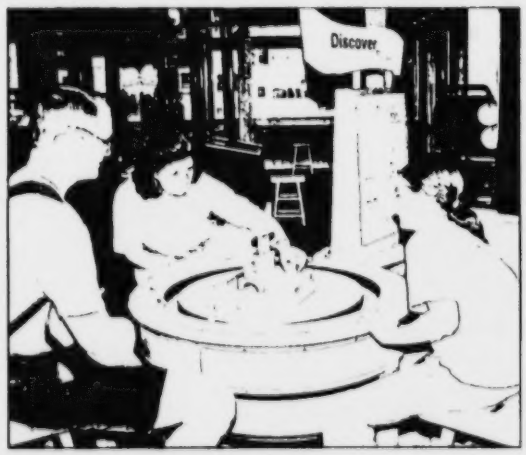
Problem: How long can you make your iron filament glow? Thomas Edison tried hundreds of times to make filaments that would glow and not burn up. He used many different materials, from cardboard to bamboo. Edison was persistent—he never gave up trying until his project worked! Consult the Lemelson webpage for complete forms and instructions for doing this experiment.
www.si.edu/lemelson/edison/html/making_a_light_bulb.html

IN THE EXHIBITION

Look at the stroller in the IDEO exhibit section. Can you follow the steps of the process by which the IDEO team developed the stroller? What was the original concept? What new ideas were incorporated into the vehicle in the course of the team development process? How was the final product different from the original idea?

The Invention Playhouse





Clockwise, from top: Magnet Table, Rocky Blocks, Whirligigs, and Tessellation Puzzles.

Photos by Terry C. McCrea and Richard Strauss, courtesy of Smithsonian Institution

The Invention Playhouse

Four Approaches to Playful Invention

In this section of the exhibition visitors explore four playful approaches that are frequently cited by creative adults as significant to the development of inventive minds. These approaches form an interesting parallel to the four kinds of children's play that child-development experts identify as more or less universal: exploratory play, pretend play, social play, and play with patterns, puzzles, and problems.

1. Exploratory Play—tinkering, experimenting, getting to know tools and materials

Touching, patting, banging, pouring, tasting, looking, listening, pulling apart, putting together—these are some of the many ways that children explore and experiment by playing. Through these activities—done with increased skill over the years—children learn the physical properties of various materials, begin to count and measure, recognize shapes and patterns, develop language and motor skills, and begin to make sense of the world around them. Many inventors seem to retain the curiosity that children have. Their mastery of their craft may be based on a field of study, but more often than not it also comes from constantly exploring and experimenting with their tools and materials. Inventors are always asking "What if I tried this? What if we did it that way?"

CLASSROOM ACTIVITIES

Provide Hands-on Experiences

Encourage children to use all of their senses and their entire bodies. Our culture places great emphasis on visual and auditory experiences, but it is also important for children to develop their sense of taste and touch, as well as small and gross motor skills. For younger children, play involving water, sand, clay, Play-Doh, blocks, and other materials continues to be essential.

Invention Walks

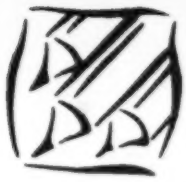
Take kids on invention walks around your neighborhood or school. Assign a tape recorder and have children call out the things they see that have been invented. Children will soon realize that, apart from our natural world, everything has been invented, and improved upon, by men and women. Ask children to design or re-design their classrooms, schoolyards, and homes. They will come up with some wonderful improvements, as well as some wacky ones! And they will be thinking the entire time.

Make Junk Bags

Fill brown lunch bags with common items found around the school or home, making sure that each bag has identical objects like paper plates, paper clips, elastics, tape, felt pieces, etc. Ask groups of three or four children to "invent" something using the items from the bags. Also, they must give their inventions a name and offer a plan for marketing the finished products. Perhaps the most surprising result of this activity will be that each group, using the same materials, comes up with something entirely different.

IN THE EXHIBITION

Encourage students to try out the hands-on activities, including the Rocky Blocks building challenge. Rocky Blocks put a new spin on an age-old challenge—building a tower of blocks—by resting a tabletop on a wobbly hemisphere rather than on a steady surface. Individuals, families, and other visitor groups can collaborate on solving a complex problem involving balance, center of gravity, weight, structure, and height. Visitors try and try again until their towers reach satisfactory heights; each toppling brings experience that informs refinements of an initial idea.



2. Pretend Play—developing imagination, language, problem-solving skills, and understanding of symbolism, analogy, and metaphor

As they play with dolls or action figures, make up stories, become lions and tigers, or sail the seas in cardboard boxes, children are using and developing their imaginations. They begin to navigate with ease between the real and imaginary worlds while maintaining clear boundaries between what is real and what is fantasy. They are manipulating symbols and metaphors by substituting one object for another or creating a new object entirely. They are also learning how to imagine something and then give it concrete expression—through a story, a drawing, a play, or an object that they create or transform. This process in itself generates even more ideas. Child-development specialists see a strong connection between children's levels of pretend or symbolic play and their ability to engage in divergent or creative thinking—to generate a variety of ideas and associations to solve a problem, come up with new ideas, free associate, and show fluidity and independence in thinking.

A common characteristic of inventors and other creative people is their ability to imagine, to think visually and spatially. Many inventors talk about the experience of seeing an invention whole in their mind's eye before they even know if it will work or not. This kind of thinking requires knowledge of tools and materials. It also takes time and space for reflection—it could be on a walk, in the shower, or sitting in the subway. Many inventors featured in this exhibition talk about having a "dreaming place."

When asked to pick their favorite tool, inventors often choose a pencil or a notebook. That's because a second common characteristic of inventors is that they capture their ideas. They draw them, write them down, build models and prototypes, or create simulations. It's not enough to have dreams—you must capture and express them!

CLASSROOM ACTIVITIES

Inventor's Notebook

Have students keep an inventor's notebook—a journal containing notes and jottings or a sketchbook or set of drawings.

Prototypes

Models or prototypes of invention ideas can be very rough, but the experience of building and testing an idea can help to move it along as well as show where problems are.

Thinking Environment

Creating a thinking environment—Creating this space at home and school for our children involves a delicate kind of ecosystem: a place where there is time for in-depth assignments; an atmosphere where risks can be taken and mistakes made; a place where children can think visually and kinesthetically as well as verbally. Some ways to get kids thinking about invention include: reading inventor biographies and personal stories, creating zany inventions, thinking about improvements to familiar things already invented, and forecasting new things that might be invented in the future.

Dreaming Place

Help children find a "dreaming place"—a space to read, think, draw, or just daydream.

IN THE EXHIBITION

Encourage children to try the activities at the Magnet Wall, where they must use familiar objects like kitchen utensils in unfamiliar ways, such as building a ramp or making a face. The large Magnet Wall offers three novel invention challenges using kitchen utensils that are magnetized and affixed to the fourteen-foot-long structure. Visitors are challenged to create faces and other constructions, spell out their names, and build trackways for rolling a ball down a magnetized ramp.

3. Social Play—learning to communicate

As children mature, they begin to interact more with other children. They learn about sharing and taking turns; about being in groups or on teams. They begin to understand that just because they know something does not mean that others know it too. They are learning to communicate, to say what they want to do or not do. This type of play is called "social play," and it forms the basis for personal and social communication throughout life.

In fact, communicating with others is an important part of the invention process. Brainstorming is a technique that many people use to get new ideas on the table. While an invention is being developed, many inventors report discussing and testing it with family, friends, or colleagues. Inventors today often work as members of teams in laboratories or corporations. You will find that many of the inventors featured in this exhibition work this way.

The Invention Playhouse

CLASSROOM ACTIVITY

Brainstorming

To help children come up with ideas, allow them to brainstorm. Have them quickly list whatever ideas come into their minds, no matter how wild. When the ideas stop coming, have them pick the best ones and test them out. You can give children practice in brainstorming by asking them to think of different and unusual uses for a paper bag, a coat hanger, or a paper clip. Often when we ask children to brainstorm, we give everyone an opportunity to present an idea and then we move on to something else. Stretching ideas—and children's minds—should involve keeping responses coming with a particular object, even if it means circling the classroom several times or driving several more miles with your children in the car, as you expand their thinking skills.

IN THE EXHIBITION

invention at play

Encourage children to work together. Many of the activities in the exhibition were designed to make it easier for groups of people to problem solve, talk, and work together. Whirligigs invite play in a multimedia activity where groups of students invent wind-powered devices and then try out their designs in front of blowing fans. They can test and then refine initial ideas through repeated trials as they play with principles of aerodynamics, balance, and angular momentum.

4. Play with Patterns, Puzzles, and Problems

Have you ever watched a child use a cup for a hat? Or a hat for a bowl? Because they don't necessarily know the accepted uses of many things, children invent their own. And often, even when they learn the "right" use, kids find new and imaginative ways to play with familiar things.

At the same time that children are learning that hats go on heads and cups go on tables, they are also learning about other kinds of patterns and associations. Through play, they are learning that some things are "the same" and some things are "different"; they are learning about categories like "animal" that can contain many different kinds. They may even play with puzzles that have pieces that "fit" and "don't fit." As they grow and develop, children become increasingly sophisticated in recognizing and understanding categories, patterns, and associations.

It is important for children to observe closely, to learn how things work and where things go. At the same time, child-development experts tell us that it is also essential for kids to explore and make mistakes, to value that which is "out of synch" as well as that which fits the mold. Through play, especially exploratory and pretend play, children can try out both making and breaking patterns. It is this facility with playing both inside and outside the box that develops good problem-solving skills.

Inventors seem to be people who are always asking why things can't be done a different way. Inventors often see associations and connections that aren't obvious to others. A number of inventors featured in this exhibition have modeled innovative technologies on patterns in nature.

While some inventions come from finding new patterns, others come from breaking out of fixed sets and modes of thought. Experts who study creative problem solving say that an important obstacle to problem solving is a fixed set of assumptions or an unchanging approach. Often a radical rethinking or restructuring of a problem is needed before a solution can be found. Inventors report that sometimes this comes from working directly on the problem; at other times it comes from setting it aside and letting it "incubate."

Encourage Problem-solving Skills

Playing with puzzles or matching activities helps children to use what they already know to solve a problem. As children grow older, find more open-ended puzzles and problems for them to solve, ones that require setting aside assumptions, breaking usual patterns, and finding new rules.

Develop Invention Ideas

Remind children that it is important to get information to make an invention successful. Suggest that they answer the following questions:

- Does this invention already exist?
- Where can I get the facts?
- Is my idea practical and safe?
- Will my invention be used?

Also, children should survey the needs of their family members, neighbors, or friends in developing their ideas.

IN THE EXHIBITION

In the Invention Playhouse visitors can try a variety of activities that encourage inventive skills. Have the kids try the Tessellations (pattern-making) activity. They can make patterns that mimic natural forms such as stars or flowers, or they can make up their own patterns. Tessellation puzzles promote spatial reasoning and problem-solving skills through pattern-making activities that offer mathematical and artistic entry points into play. Visitors may choose to copy Middle Eastern tile mosaics or Native American geometric pottery patterns, or break with tradition and create innovative designs of their own.

Issues in Play

Past, Present, and Future

This area, with its banner message, "Shape your thinking through play," encourages visitors to reflect on questions and debates in the history and future of play.

Experimental playthings from the Lifelong Kindergarten program at MIT's Media Lab demonstrate how microprocessors equipped with sensors and tiny motors can be used with traditional craft materials in new kinds of play. Examples of these playful inventions are featured in the exhibition. They also form the basis for gallery demonstrations.

Mitchel Resnick of the MIT Media Lab with his LEGO robot
Courtesy of the MIT Media Laboratory

A collage of historic and current toys and games, including many artifacts from the collections of the National Museum of American History, resonate with visitors' recollections about play. Questions in this area include: "Have you ever played with toys and games like those in the nearby cases and drawers?" and "Do you see a link between how you played as a child and what you do now?" Responses from inventors and innovators from Lemelson Center interviews and other sources are displayed next to their favorite playthings.

Questions about the future of play, its forms and implications, are a natural consequence of exhibitions like this one. Many of the objects in this exhibition are three-dimensional manipulatives, yet our children will live in an increasingly "digital" world. How will the requirements of this new frontier impinge on our abilities to play, invent, and create in the future? Will we become less skilled at those capacities explored in the exhibition as a consequence of our immersion in digital play? *Invention at Play* highlights and seeks to foster the debate on these and other related issues.

INVENTION AND PLAY QUOTATIONS

"I don't draw a line between play and work."
Newman Darby, sailboard inventor

"All sorts of things can happen when you're open to new ideas and playing around with things."
Stephanie Kwolek, Kevlar inventor

"An advisor once told me, 'A wise man finds no distinction between work and play.' I definitely agree with that."
James McLurkin, robotic ants inventor

"Always listen to children … they might have ideas we've never thought of."
Alexander G. Bell, telephone inventor

"Flexibility of mind is a fundamental aspect of invention and innovation."
John Fabel, Ecotrek backpack inventor

"Anyone can become an inventor, as long as they keep an open and inquiring mind and never overlook the possible significance of an accident or an apparent failure."
Patsy Sherman, Scotchgard inventor

"While ideas are conceived in individual minds, they are seldom born in isolation and rarely realized alone."
Jerry Hirshberg, founder of Nissan Design International

"Don't fear failure. Don't crave success. The reward is not in the results but rather in the doing."
Wilson Greatbatch, inventor of the implantable cardiac pacemaker

"To invent, you need a good imagination and a pile of junk."
Thomas Edison

"Imagination is more important than knowledge. For while knowledge defines all we currently know and understand, imagination points to all we might yet discover and create."
Albert Einstein

"You can discover more about a person in an hour of play than in a year of conversation."
Plato

"A mind once stretched by a new idea never regains its original dimensions."
Oliver Wendell Holmes

"Life is a game in which the rules are constantly changing."
Quentin Crisp

"If you want creative workers, give them enough time to play."
John Cleese

"Imaginative play is a key that opens the doors of intuition."
Frances E. Vaughan

Teacher Resources and References

Applicable National Standards for the *Invention at Play* Exhibition

Three basic national sets have been selected: the National Science Standards by NSF, the National Technology Standards by ITEA, and the National Social Studies Standards by the NCSS. These are the three sets most applicable to the subject matter of the exhibition. Other standards may be considered as circumstances warrant.

Invention and Play Process Standards

The role of troubleshooting, research and development, invention and innovation, and experimentation and problem solving.
Standard 10, page 106 STL

Abilities of technological design and understanding of science and technology. Experience with design and problem solving. Meeting human needs and solving human problems.
Standard E, page 190 NSS

The Design Process

Understanding the design process. Identifying problems and developing solutions. The ability to model, prototype, and evaluate.
Standard 9, page 103 STL

Science as Inquiry

The ability to do scientific inquiry. The ability to understand the scientific method. The ability to identify questions, analyze data, develop descriptions and models, and think critically and logically.
Standard A, page 121 NSS

Inventors Featured in *Invention at Play*

Newman Darby	NSS	Motion and Forces	Standard B	Page 149
	STL	Designing Objects/Testing	Standard 9	Page 103
	STL	Design Process	Standard 11	Page 116
Sally Fox	NSS	Populations Resources	Standard F	Page 166
	NSS	Science and Society	Standard VIII	Page 99
Alexander G. Bell	NSS	History of Science	Standard G	Page 171
	NSS	Science as Inquiry	Standard A	Page 143
Paul MacCready	NSS	Life Science Adaptations	Standard C	Page 155
	NSS	Technology and Design	Standard E	Page 161
James McLurkin	NSS	Life Science Organisms	Standard C	Page 127
	STL	Invention as a Process	Standard 10	Page 110
Chuck Hoberman	STL	The Designed World	Standard 20	Page 191
	NCSS	Global Communities	Standard IX	Page 102
IDEO	NCSS	Interactions	Standard V	Page 91
	NCSS	Technological Choices	Standard VIII	Page 99
Stephanie Kwolek	NSS	Science as Inquiry	Standard A	Page 143
	NSS	Properties of Materials	Standard B	Page 123
Ann Moore	NCSS	Global Communities	Standard IX	Page 102
	NCSS	Cultural Diversity	Standard I	Page 79

Standards Publications

National Science Education Standards. Washington, D.C.: National Academy Press, 1996. (NSS)

Expectations of Excellence: Curriculum Standards for Social Studies. Washington, D.C.: National Council for the Social Studies, 1994. (NCSS)

Education Standards for Technological Literacy: Content for the Study of Technology. Reston, Va.: International Technology Education Association, 2000. (STL)

Family Guide and Resources

A family guide containing exhibit-related activities and invention resources for parents and other caregivers is available from the *Invention at Play* website at *inventionatplay.org*.

For more information and additional resources, visit the Lemelson Center's homepage at *www.si.edu/lemelson*.

Selected Bibliography

Ambrose, Don. *Imagitronics: Mind-Stretching Scenarios to Launch Creative Thought and Develop Problem-Solving Skills.* Tucson, Ariz.: Zephyr Press, 2002.

Caney, Steven. *Steven Caney's Invention Book.* New York: Workman Publishing, 1985.

——. *Steven Caney's Toy Book.* New York: Workman Publishing, 1985.

Costa, Arthur L., ed. *Developing Minds: A Resource Book for Teaching Thinking,* 3rd ed. Alexandria, Va.: Association for Supervision and Curriculum Development, 2001.

Delisle, Robert. *How to Use Problem-Based Learning in the Classroom.* Alexandria, Va.: Association for Supervision and Curriculum Development, 1997.

Flack, Jerry P. *Inventing, Inventions, and Inventors: A Teaching Resource Book.* Englewood, Colo.: Teacher Ideas Press, 1989.

Haas, Carolyn, and Anita Friedman. *My Own Fun: Creative Learning Activities for Home and School, Ages 7–12.* Chicago: Chicago Review Press, 1990.

Historical Inventions on File: Understanding Science by Re-creating Key Inventions. New York: Facts on File, 1994.

Innovative Lives: A Teacher Resource. Washington, D.C.: Smithsonian Institution, 1998.

Innovative Lives: Classroom Enrichment. Washington, D.C.: Smithsonian Institution, 1998.

Macaulay, David. *The New Way Things Work.* Boston: Houghton Mifflin, 1998 (also available on CD-ROM).

Machines and Inventions. Alexandria, Va.: Time-Life Books, 1993.

Melin, Jacque. *Passport to Learn: Projects to Challenge High-Potential Learners.* Tucson, Ariz.: Zephyr Press, 2001.

Murphy, Jim. *Guess Again: More Weird and Wacky Inventions.* New York: Bradbury Press, 1986.

Platt, Richard. *Smithsonian Visual Timeline of Inventions.* New York: Dorling Kindersley, 1994.

Tucker, Tom. *Brainstorm! The Stories of Twenty American Kid Inventors.* New York: Farrar, Straus and Giroux, 1995.

Wood, Richard. *Great Inventions.* Alexandria, Va.: Time-Life Books, 1995.

Additional Websites

Academy Curricular Exchange, Columbia Education Center, Science
ofcn.org/cyber.serv/academy/ace/sci/cecsci/cecsci132.html

AeroVironment
www.aerovironment.com

IDEO
www.ideo.com/ideo.asp

Lemelson Center's Innovative Lives
www.si.edu/lemelson/centerpieces/ilives/index.html

Lemelson-MIT Program Invention Dimension
web.mit.edu/invent

MIT Media Lab
www.media.mit.edu

Scholastic for Teachers
teacher.scholastic.com/lessonrepro/lessonplans/theme/inventions04.htm

Science Museum of Minnesota
www.smm.org

Related Videos

"The Deep Dive," *Nightline* 02-09-99, ABC News Home Video N990209-01 (IDEO company)

"Flying Free," *Scientific American Frontiers*, PBS Home Video SAMF9109 2000 (Paul MacCready)

Lemelson Center Videos

Electric Guitar: Its Makers and Its Players

Everyone Is an Inventor

Lewis Latimer: Renaissance Man, African American Inventor

Microrobots and the Phantom: An "Innovative Lives" Special

Mind's Eye, Mind's Invention: Chuck Hoberman's Unfolding Structures and the Math behind Them

Reinventing the Wheel: The Continuing Evolution of the Bicycle

She's Got It! Women Inventors and Their Inspirations

Sound, Light, Edison! Celebrating 150 Years of Invention

For information on ordering Lemelson Center videos, please see the Lemelson Center webpage:
www.si.edu/lemelson

Teacher's Notes

Acknowledgments

The Educators' Manual was developed by Michael Judd, Jane Lacasse, Monica Smith, and Katie Reilly.

Thank you to the following reviewers

Cynthia Baker
Teacher, Hine Junior High School

Ann Erickson
Art Specialist, Neil Armstrong Elementary School

Megan Garnett
Teacher, Robinson Secondary School

Syd Jacobs
Homeschool Parent

Karen Kenna
Assistant Principal, Lynbrook Elementary School

Eric Klopfenstein
Teacher, Ormond Stone Middle School

Eleanor Lash
Teacher, Sidwell Friends School

Anita Levine
Teacher, Flower Hill Elementary School

Kirsten Sandberg
Teacher, Smithsonian Early Enrichment Center

Virginia Singer
Teacher, Sidwell Friends School

Special thanks to

Joan Abdallah
Program Director, DC ACTS

Julie Edmonds
Associate Director, Carnegie Academy for Science Education

Luvenia A. George
Coordinator, Ellington Youth Project

Elizabeth Judd
Museum Consultant

Lemelson-MIT Program, Lemelson Assistive Technology Development Center.

Lemelson Center

Arthur P. Molella
Director

John Fleckner
Associate Director

Claudine Klose
Program Manager

Joyce Bedi
Historian

Chris Broda-Bahm
Public Affairs Specialist

Maggie Dennis
Project Historian

Yolonda Earl
Management Support Assistant

Tanya Garner
Program Specialist

Michael Judd
Senior Educator

Alison Oswald
Archivist

Alison Smith
Program Specialist

***Invention at Play* Traveling Exhibition Project**

Gretchen Jennings
Project Director

Monica Smith
Project Historian/Exhibition Specialist

Anita Cater
Education Specialist

Wendy Hancock
Education Coordinator

Nobel Prize Project

Will Eastman
Project Historian and Coordinator

Gerry Rogers
Education Specialist

Fletcher Design/Washington, D.C.
Design

Jane Lacasse
Educational Consultant

Joan Mentzer
Editor

Katie Reilly
Intern

© 2002 Lemelson Center for the Study of Invention and Innovation

Smithsonian
National Museum of American History

The Museum is located at 14th Street and Constitution Avenue, N.W., Washington, D.C. Hours are 10 a.m. to 5:30 p.m.; closed December 25. Admission is free. Museum exhibition areas, performance spaces, and most rest rooms accommodate wheelchairs. For further information call 202-357-2700 (voice) or 202-357-1729 (TTY) or visit *americanhistory.si.edu*.

Lemelson Center for the Study of Invention and Innovation

Invention at Play was developed by the Lemelson Center at the Smithsonian's National Museum of American History in partnership with the Science Museum of Minnesota. The exhibition, its related programs and materials, and its national tour are supported by The Lemelson Foundation and by the National Science Foundation.

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

NOTICE

Reproduction Basis

	This document is covered by a signed "Reproduction Release (Blanket)" form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.
X	This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").